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Fuel Cell Technology and Hydrogen for the decarbonisation of transport, energy and industry in Europe

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Toyota in Europe

2/3 of our products sold in Europe are made in Europe

- Began selling cars in **1963**
- **9** manufacturing plants in **7** countries
- Over **€9** billion invested since 1990
- **928,488** vehicles sold in CY2016
- **4.7%** market share in CY 2016
- Around **1,500,000** hybrid vehicles sold in Europe [YTD May 2017]
- More than **€4** billion spent with European-based suppliers per year
- Employees (approx.): **20,000** (direct / including TPCA, 50/50 joint venture Toyota/PSA Peugeot Citroën)

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Key Takeaways

Toyota is promoting H2 and Low-Carbon mobility and society.

European industry, research and policy makers (EU and national) are working close towards realising the full potential of H2 in Europe.

Toyota has an active role in European H2 and Fuel Cell research and deployment.

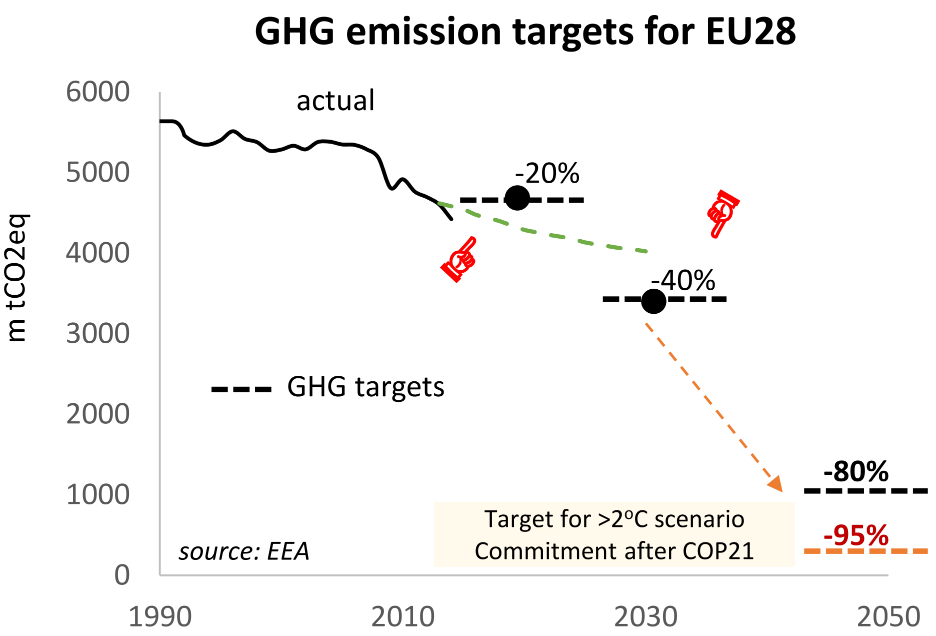
We are looking forward to further collaborations….

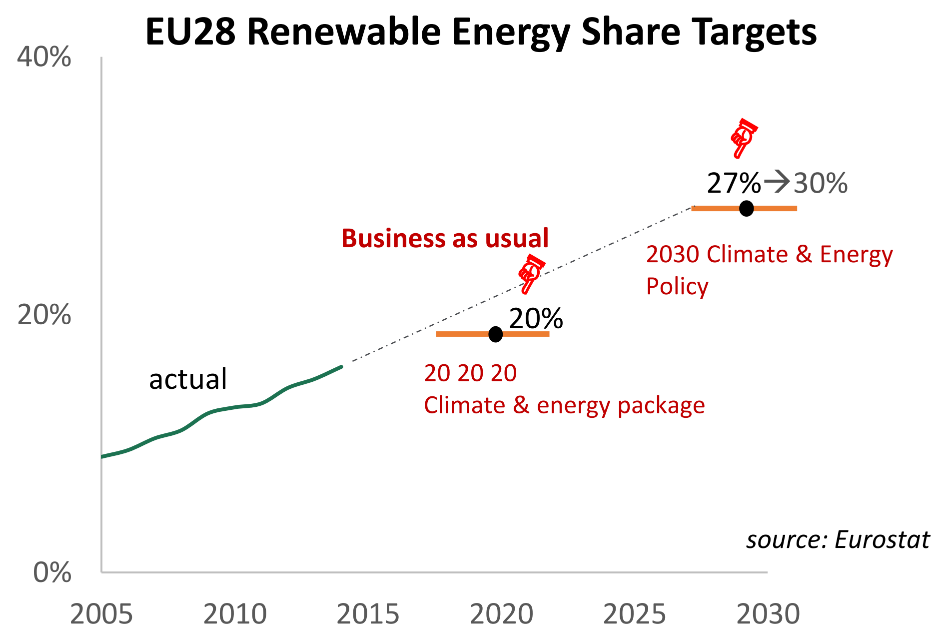
Outline

1. Background
2. Toyota's environmental challenge
3. Toyota's future mobility image and Fuel Cell mobility
4. Fuel Cell Mobility in Europe
5. Case study on Low-Carbon H2 for industrial regions

EU on track to meet its 2020 GHG and renewable targets

However, stricter policies will be needed towards 2030 and 2050 targets





- Towards the -40% GHG target, **GHG reduction via increased renewables is pursued (esp. power sector)**.
- **EU on track** to meet its **2020** and most probably its **2030 renewable energy targets.**

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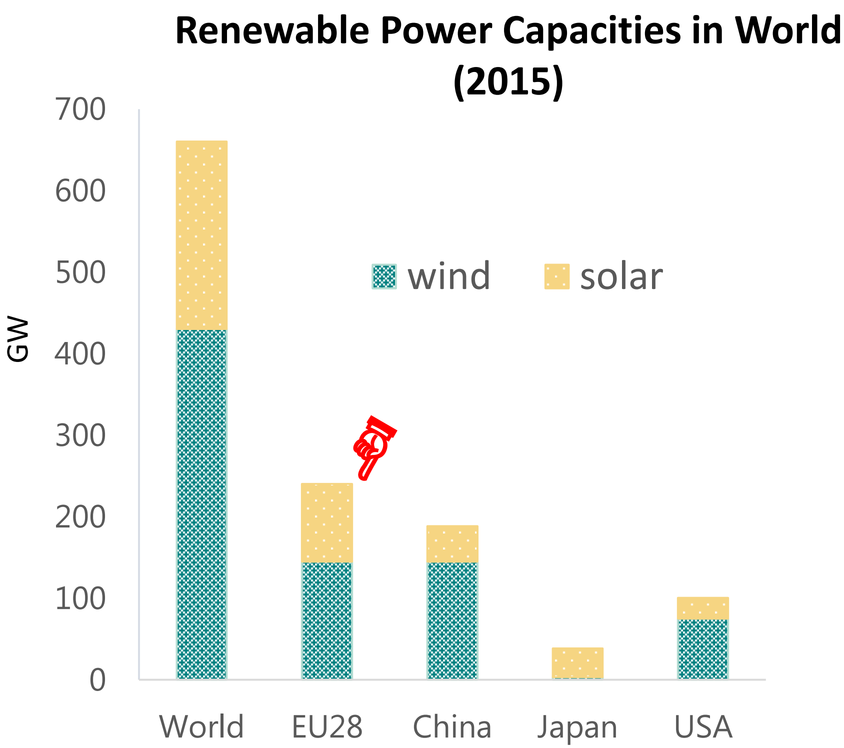
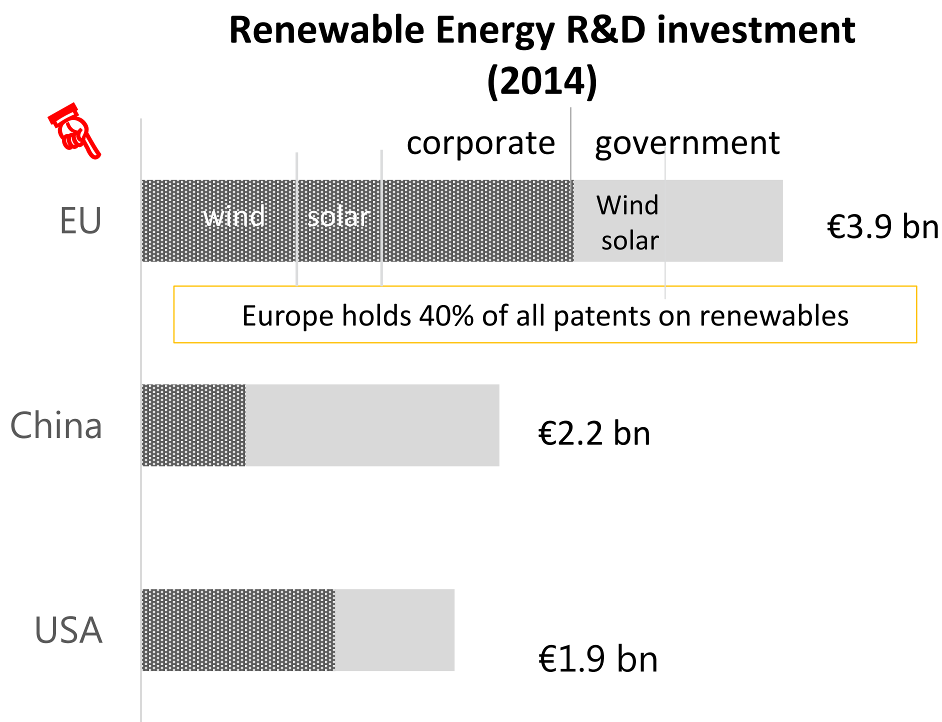
EU among wind-solar capacity and technology leaders

Significant investment in R&D and technological leadership





sources: REN21, BNEF, IEA, IMF, Oettinger,COP21

- By 2015, **35% of the world's wind and 40% of solar** capacity has been installed in EU28.
- **Europe holds 40% of all renewables' patents.** In 2015, R&D investment on wind and solar was >**€2 bn**.

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Toyota Environmental Challenge 2050

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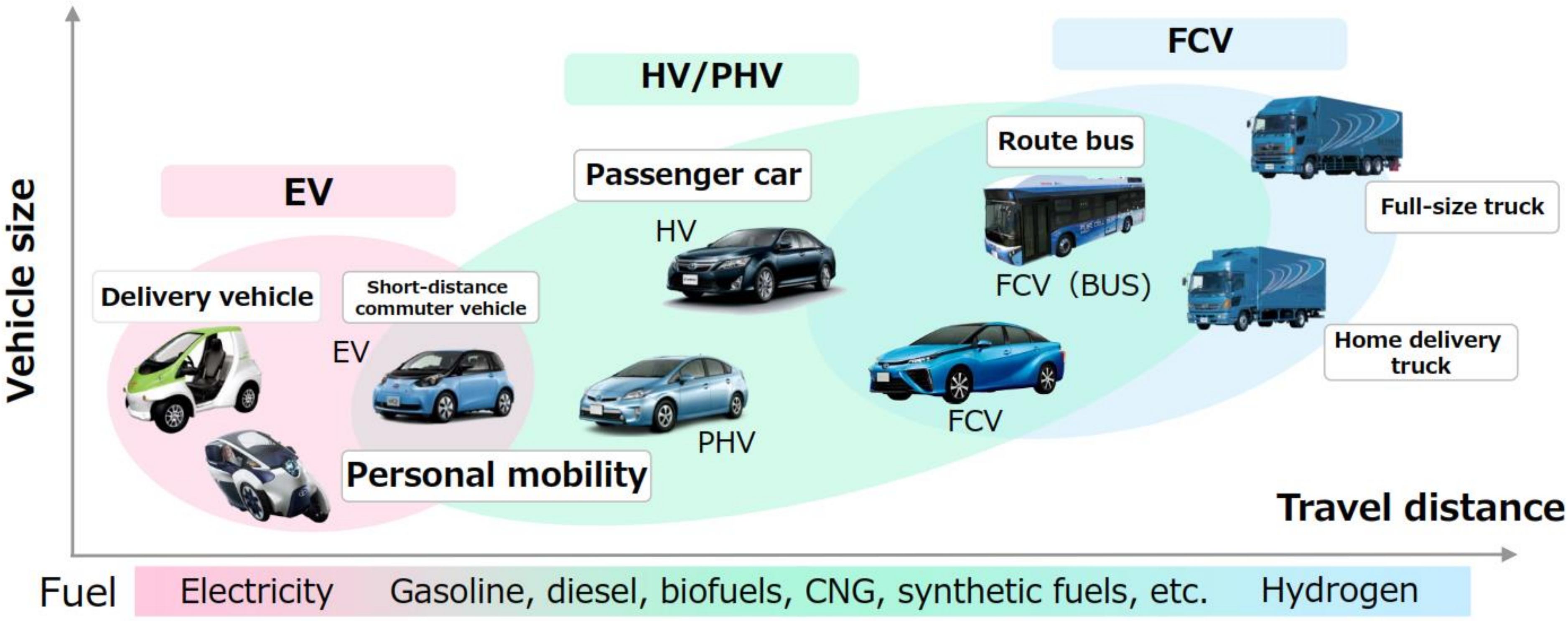
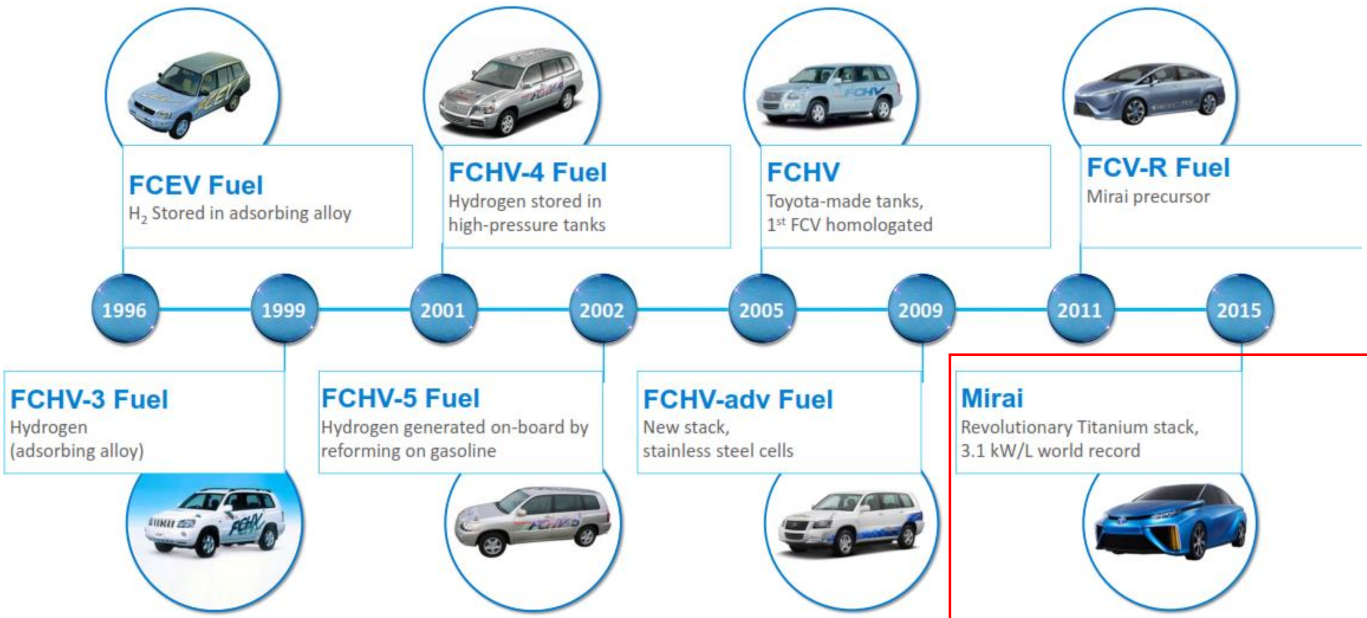
Toyota's future mobility image



Toyota’s H2 Mobility Experience and Products



Launched in 2014
>3,500 units sold globally
>110 sold in EU

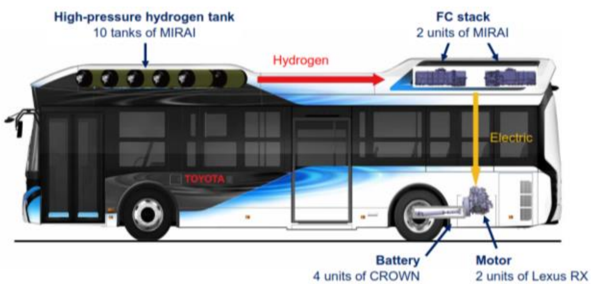
<u>Production</u>
In 2017 → 3,000 units/year
In 2020+ → 30,000 units/year

Mirai

3 minutes for refuelling

FC Forklifts

FC Buses



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Fuel Cell Mobility is spreading steadily in Europe

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Hamburg H2 Society is a good example






- 5 Hydrogen Refuelling stations for vehicles (50% of H2 is green)
- Fuel Cell powered passenger ship
- Fuel cell forklifts at Hamburg Airport since 2007
- Fuel cells for homes for electricity and heat
- Research on the use of fuel cells at Airbus
- Power to Gas station

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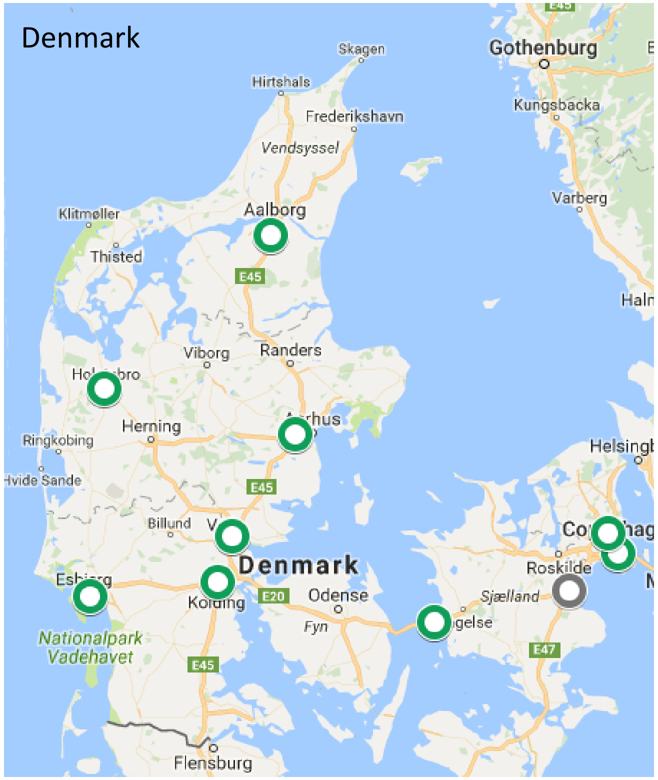
H2 infrastructure increasing steadily (incl. green H2)

Public HRS for cars (700 bars)

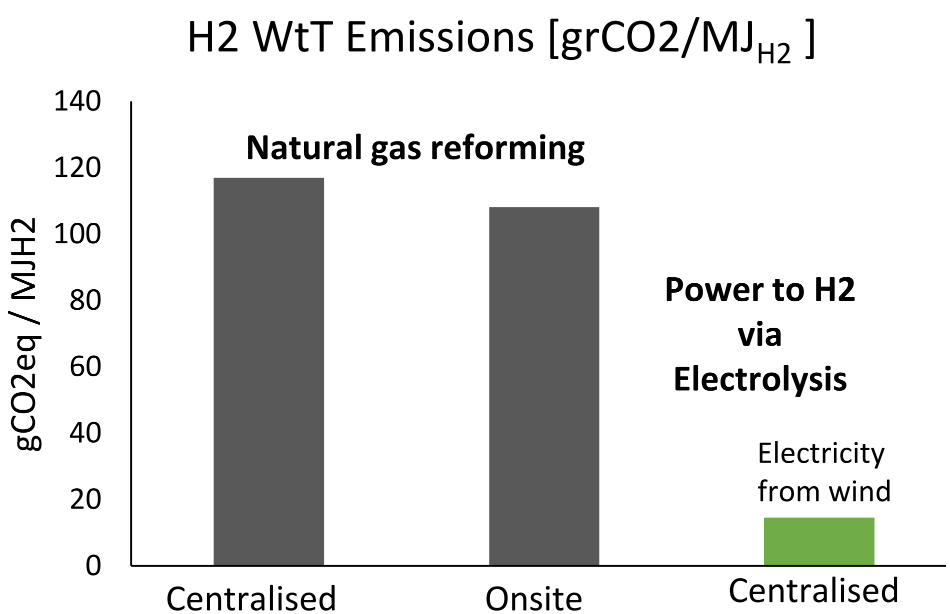
Green Stations Conventional Stations



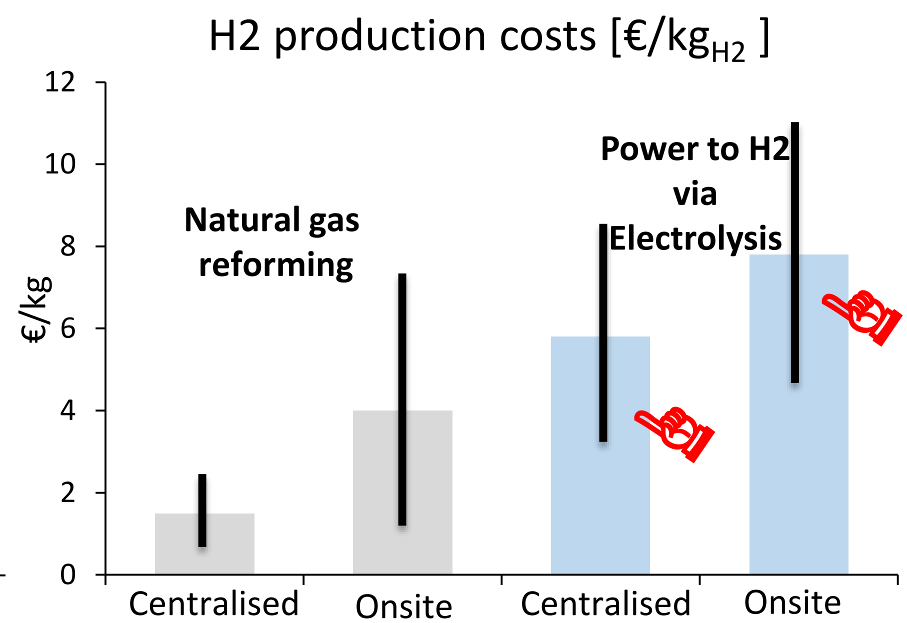
58 public H2 refuelling stations for passengers cars by the end of 2016 and 47 more planned in 2017

Case study

The competitiveness of Low-carbon H2 cost is a challenge



Source: JEC well-to-tank emissions study

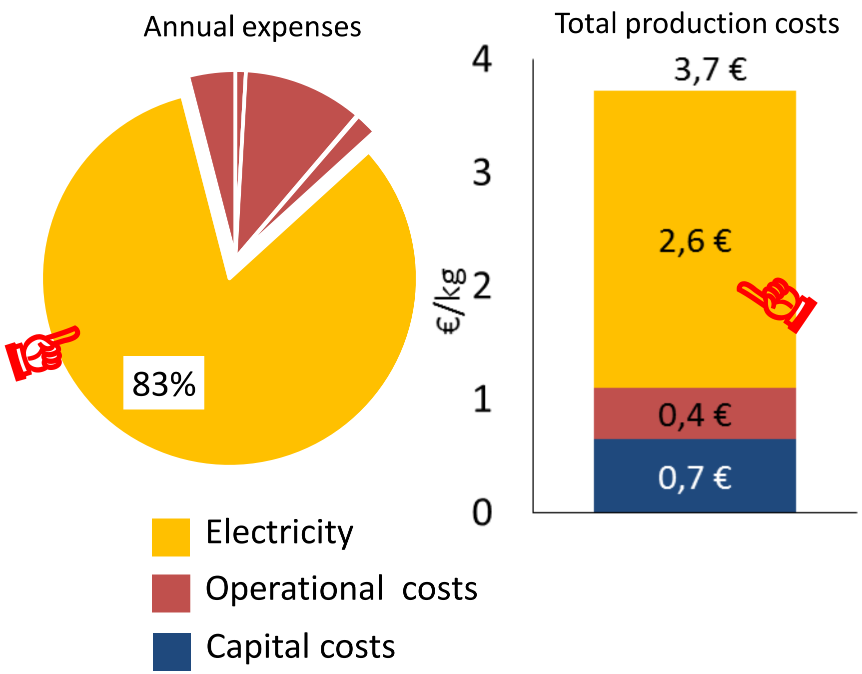


Source: Shell H2 study, 2017

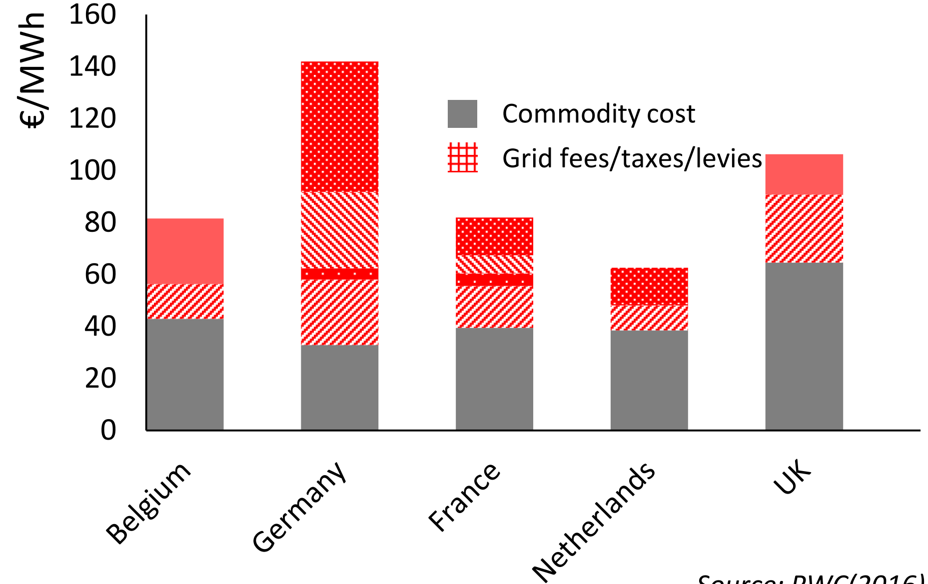
- **Power to H2** (P2H) can **minimise the CO_2 footprint** of H2 production if renewable electricity is used.
- However, **P2H via electrolysis** costs are significantly **higher than Steam Methane Reforming** (Nat. Gas).
- **It is essential to identify the factors that will lead to the reduction of H2 production cost via electrolysis.**

Electricity cost is the biggest barrier towards P2H viability

The role of electricity costs in H2 production costs



High electricity costs for mid-low-sided customers

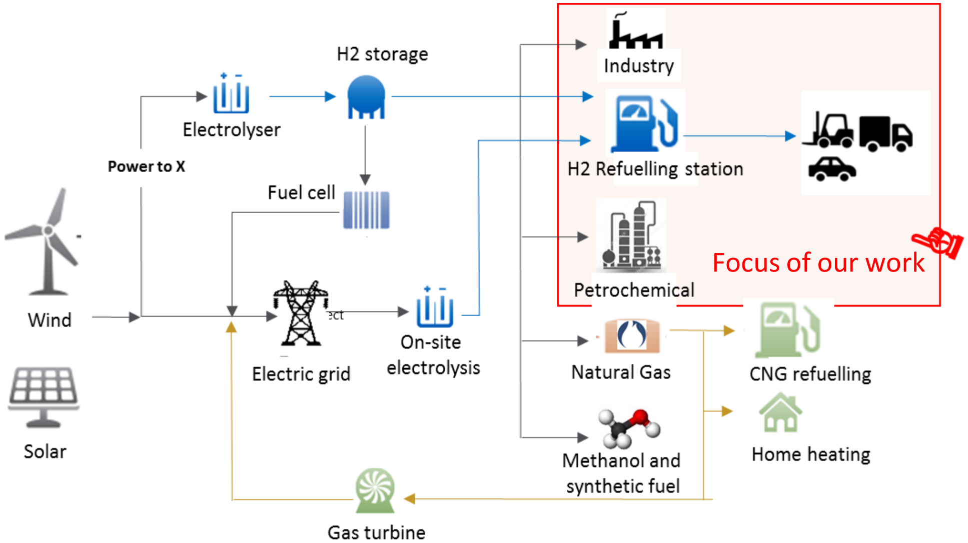


Source: PWC(2016)

1. **What are the prices of electricity for which Power to H2 economics would become more attractive?**
2. **How could small H2 consumers benefit from P2H while keeping their electricity costs manageable?**
3. **Can large H2 consumers bring the costs of P2H down, benefiting the entire H2 ecosystem?**

Industrial regions provide an advantageous P2H environment

Power to H2 sector coupling concept

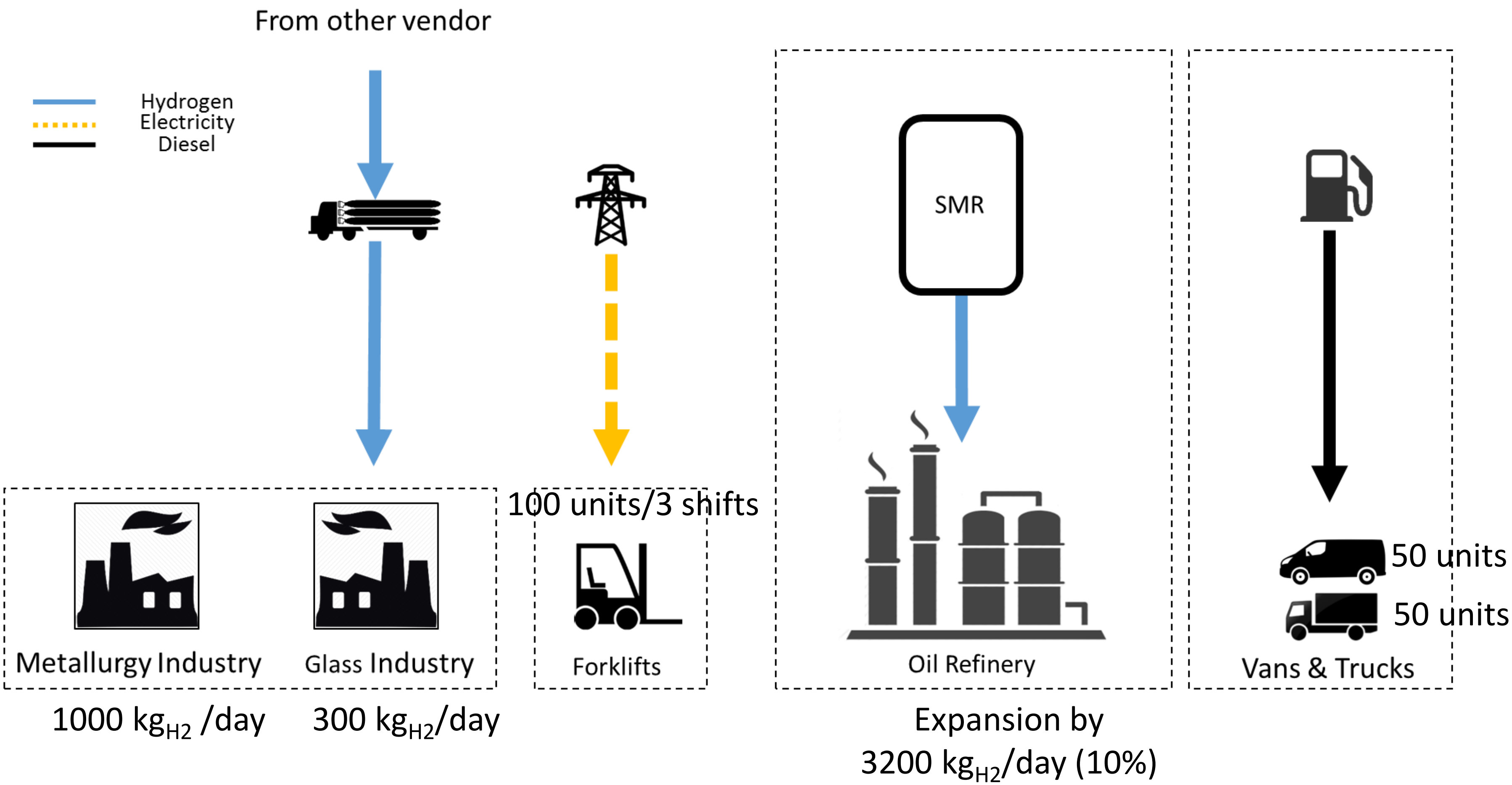


Example of industrial area of Elefsina, Greece

In an industrial area both large scale production and low transport distances can be achieved, due to:

- Industrial plants with **large H2 demands** that need to decarbonise their processes.
- **Early adopters of Fuel Cell technology** (forklifts, vans/trucks) are already existent.
- **Close proximity to fuel cell adopters**: forklifts and vans or trucks.

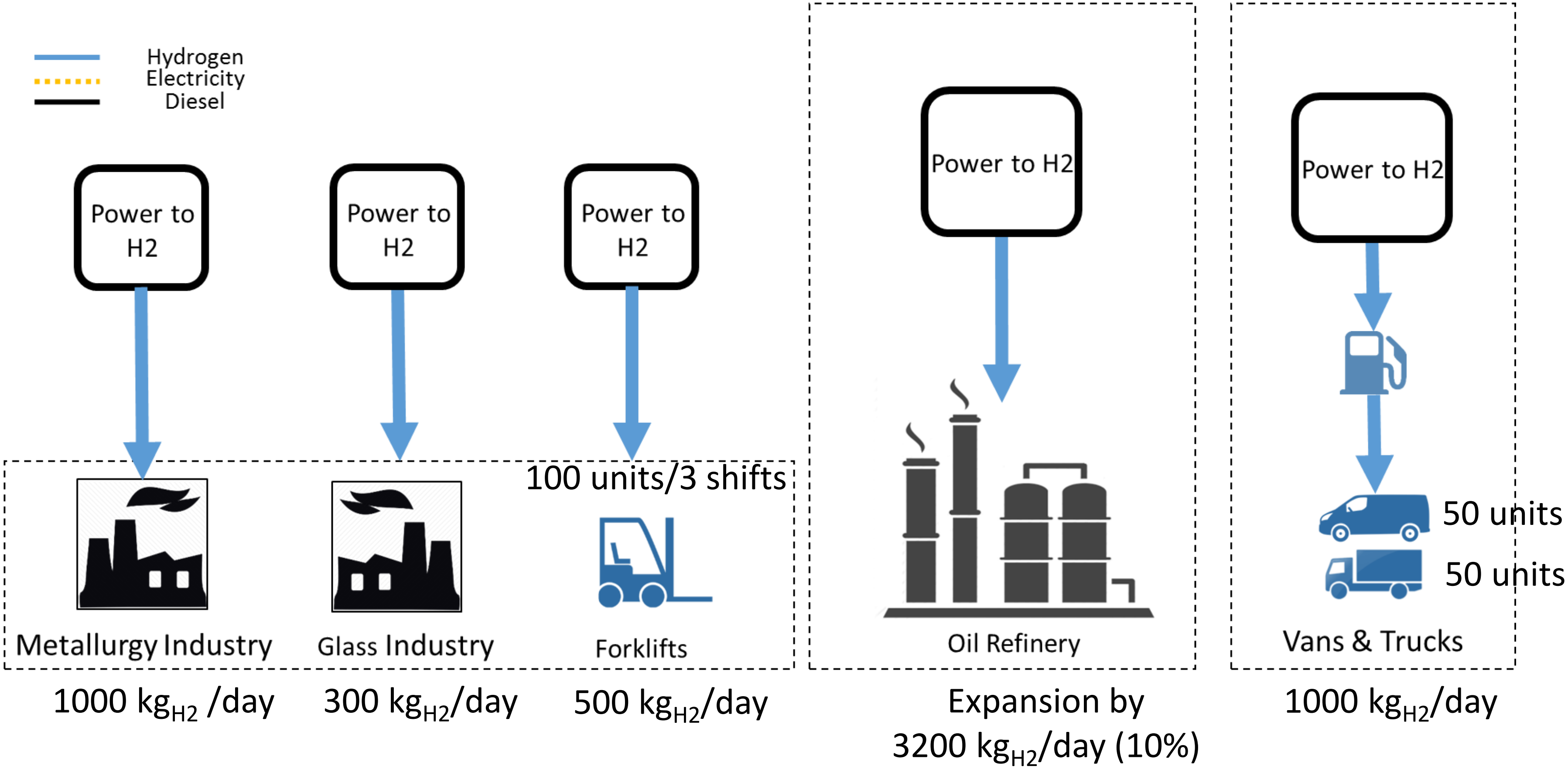
Our study: Base case scenario→ SMR H2 and delivered H2



⊖ **High CO2 emissions, high H2 costs for smaller consumers**, labour costs (battery changes **for forklifts**).

⊕ SMR is a **proven production method offering reliability**, low cost of H2 for large consumers.

Onsite scenario→ Each industry produces own H2 via P2H

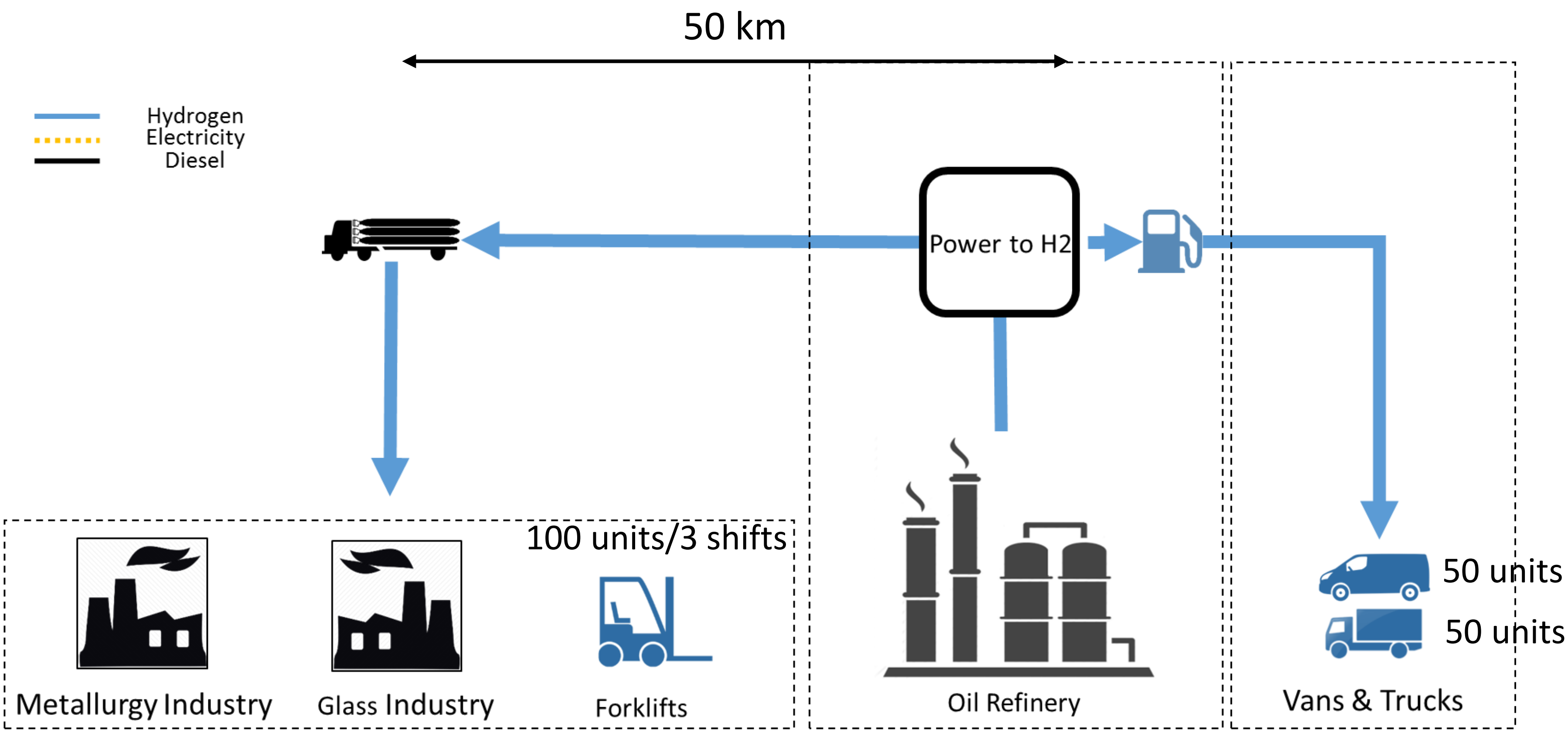


⊖ **Onsite P2H incurs large capital costs** for smaller companies and also **higher H2 costs for the refinery**.

⊕ **Lower emissions, reduced labour costs for forklifts**, could decrease H2 costs for glass/metallurgy.

Assuming green electricity with a cost of 3 €/MWh for Guarantees of Origin

Semi centralised scenario→ Refinery P2H caters for all needs



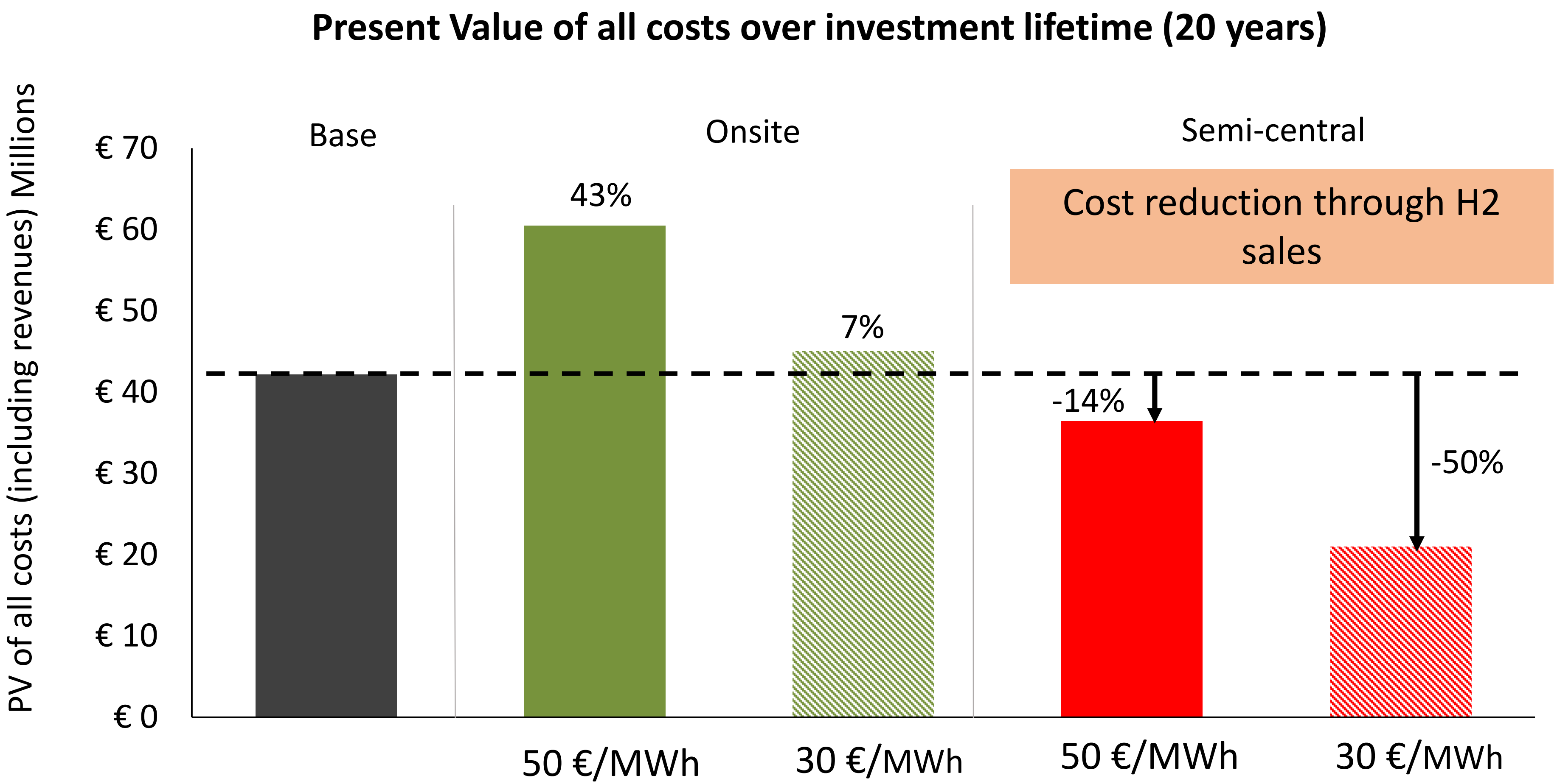
1000 kg_{H2} /day | 300 kg_{H2}/day | 500 kg_{H2}/day | Expansion by 3200 kg_{H2}/day (10%) | 1000 kg_{H2}/day

⊖ Large capital cost and **considerable operational costs** for the **refinery**.

⊕ **Lower emissions, low capital costs for other industrial players, guaranteed customers for the refinery.**

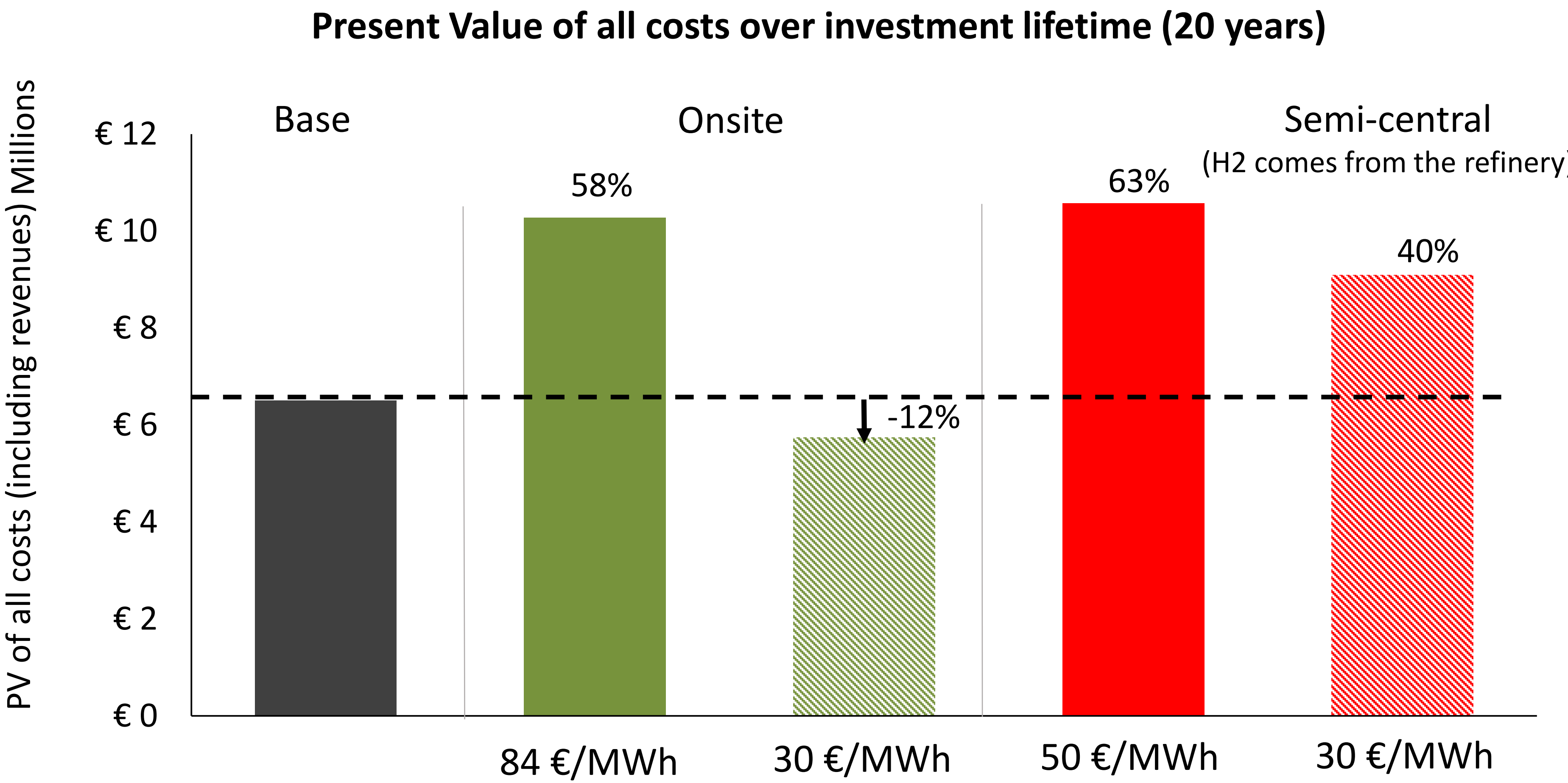
Assuming green electricity with a cost of 3 €/MWh for Guarantees of Origin

Semi-central scenario: The sales of H2 to industrial customers offset a significant part of the P2H costs for the refinery.



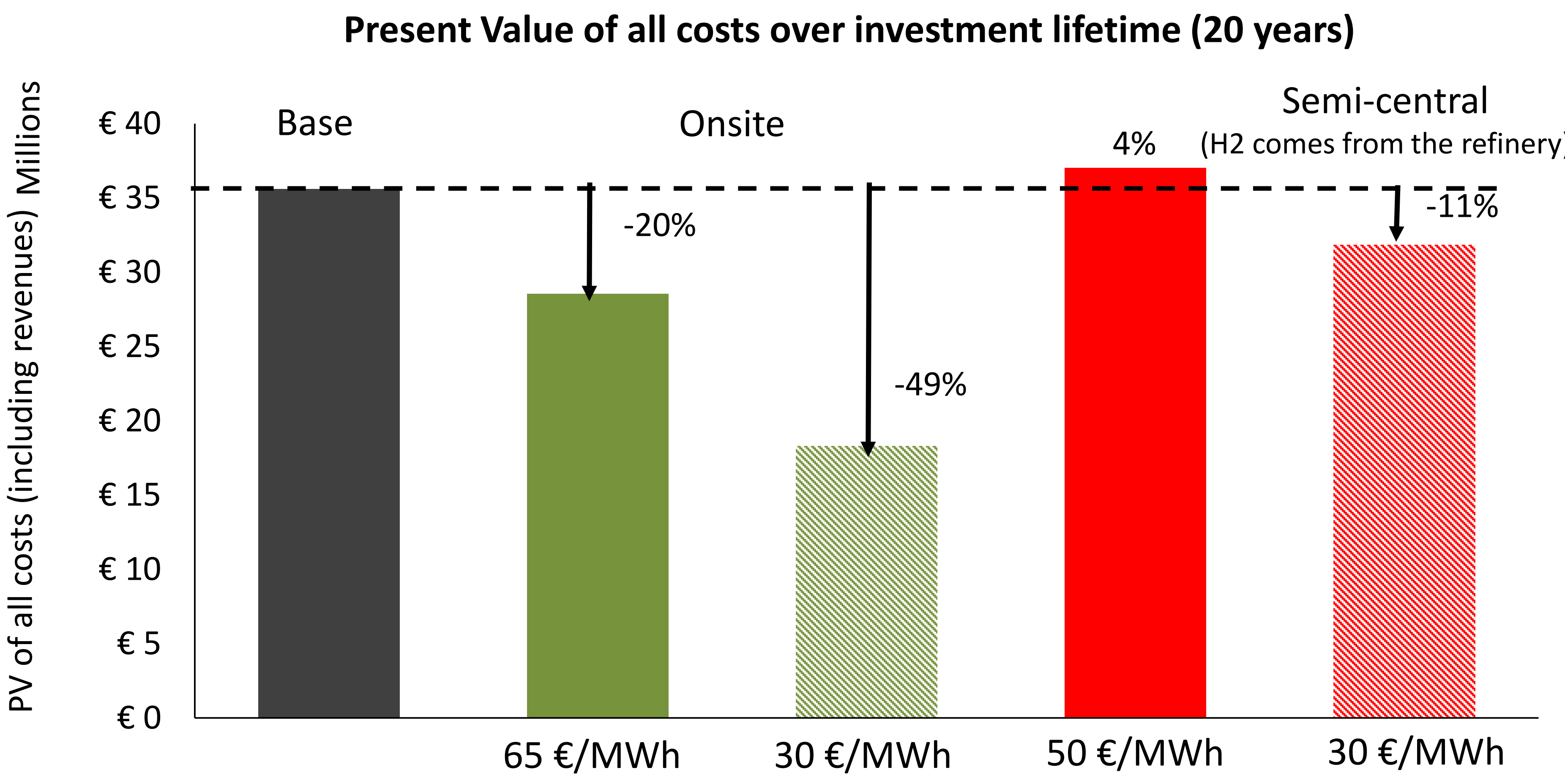
Note: Our analysis showed that **unless ETS>102 €/tonne$_{CO2}$** the ETS price is not enough to justify an investment in on-site only P2H production

P2H for Glass is a costly option due to low H2 merchant prices



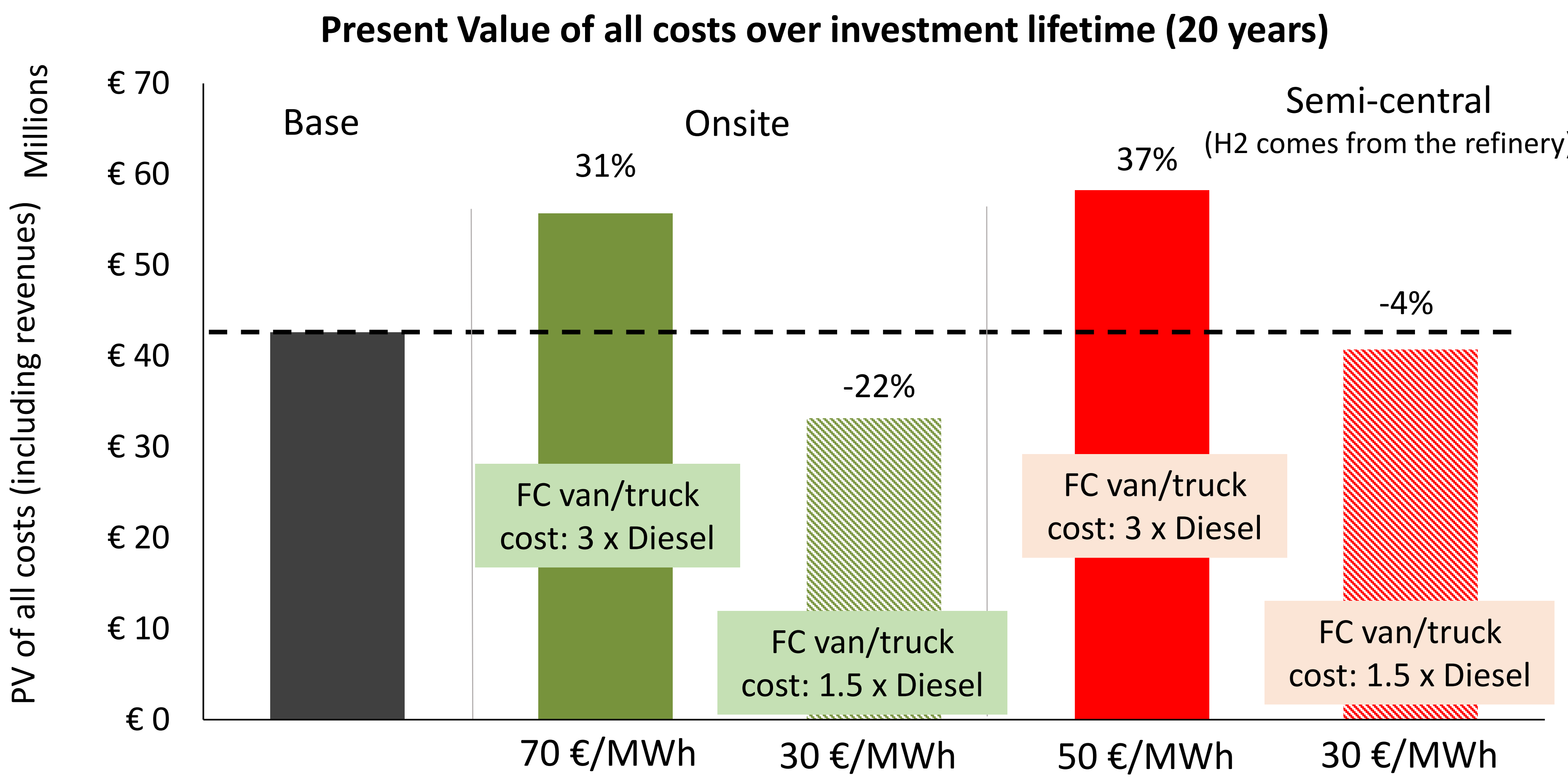
Note: Electricity prices **< 40 €/MWh** are necessary for onsite P2H to be attractive for the glass industry

P2H (onsite or semi-central) appears as a sensible option for metallurgy plants at industrial regions



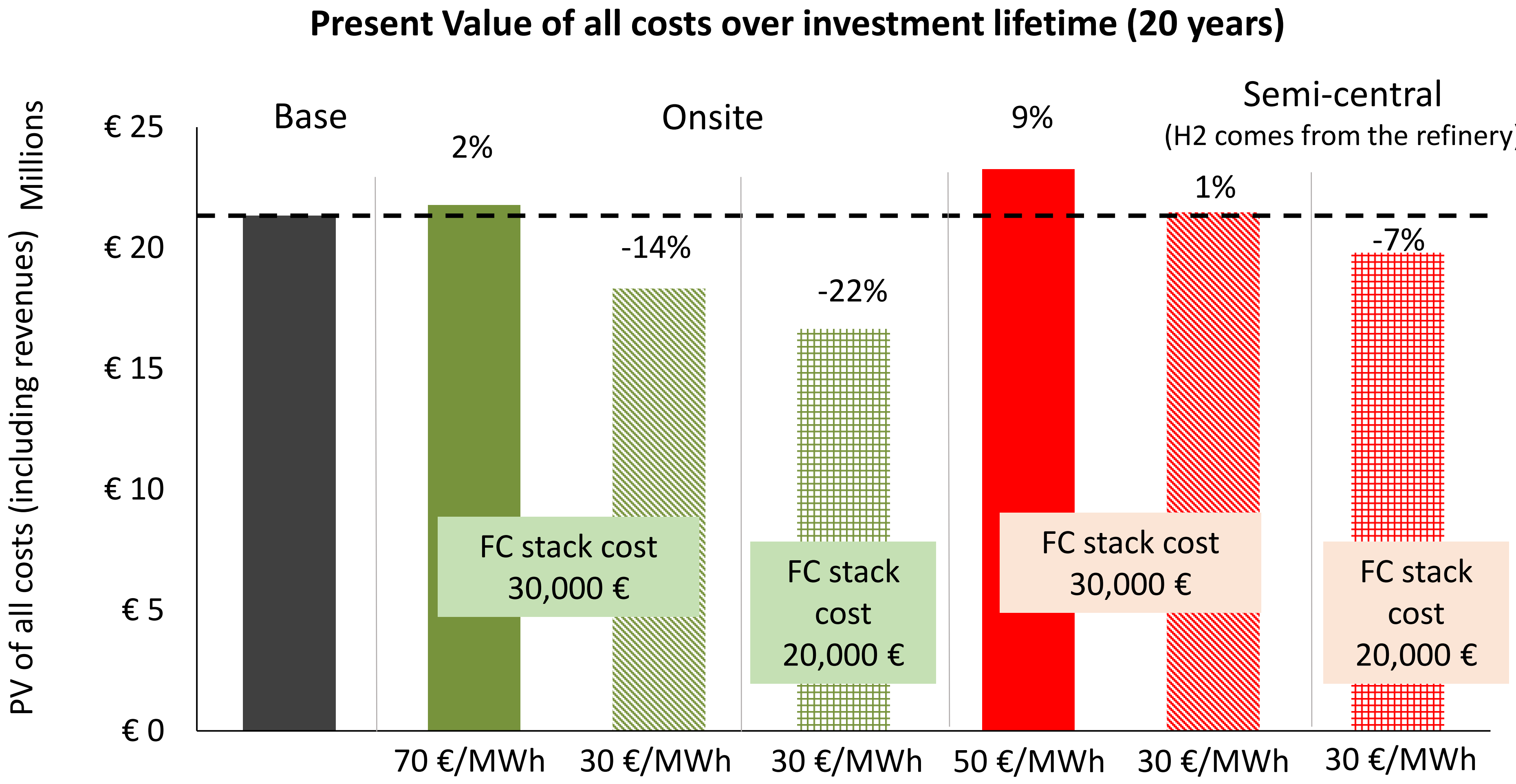
Note: Due to the **larger scale of H2 demand in metallurgy**, **semi-central P2H** is indeed **sensible but onsite P2H could help the industry realise larger savings.**

Vans and Trucks: the anticipated FC cost reduction will increase the attractiveness of the P2H business case



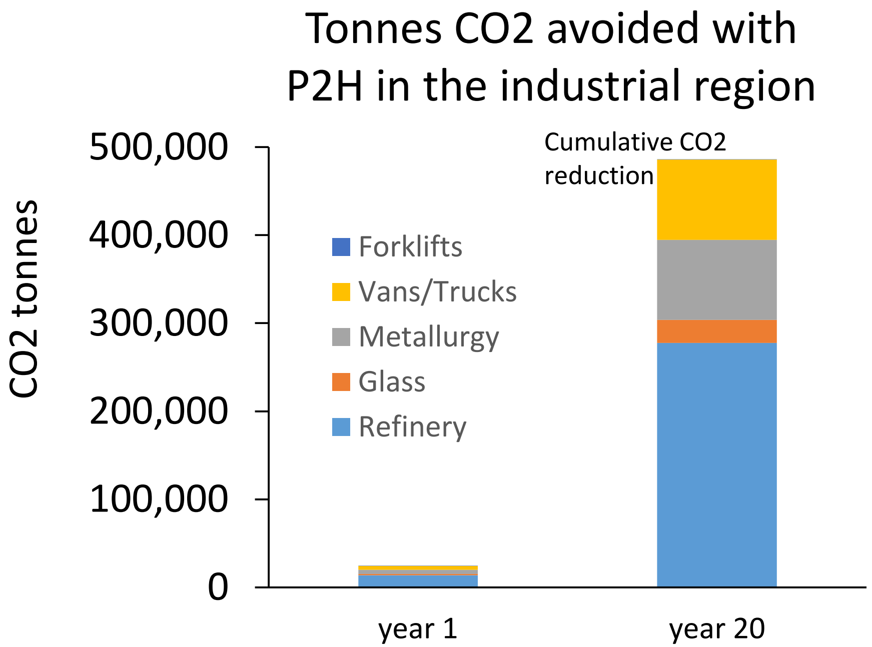
Note: At the moment there is little deployment of FC vans/trucks hence the prices are very high. We consider the 1.5 x Diesel target achievable in the next 10-15 years.

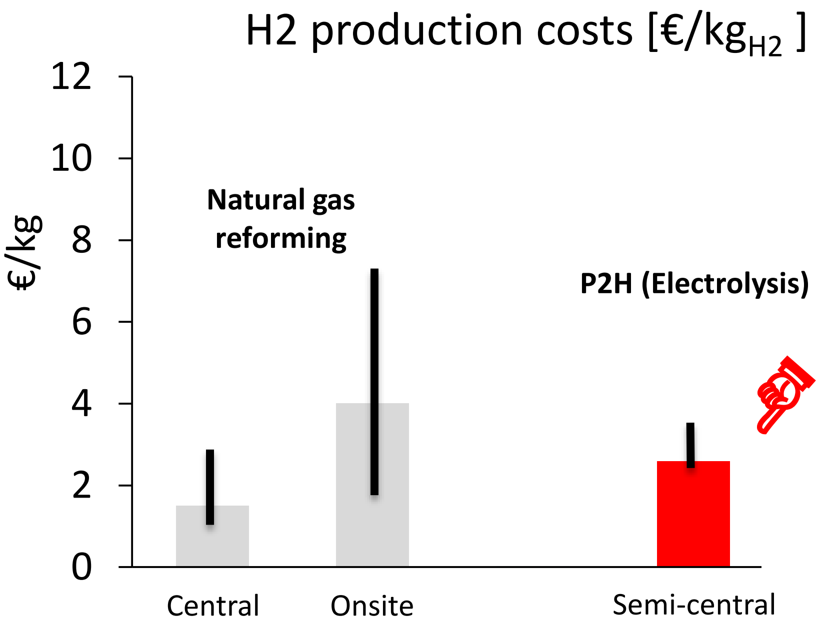
Forklifts: P2H already offers an option competitive to batteries



Note: The effect of **electricity prices is comparable to the effect of the FC stack costs.** In all cases, however, P2H and FC technology for forklifts appears meaningful for the case of large fleets with 3 shifts**.**

P2H in industrial regions can bring significant decarbonisation benefits as well as competitive H2 production costs.





- **Within 20 years, P2H adoption in and** industrial region could **save ~500,000 CO2 tonnes**.
- In a favourable electricity prices environment, the semi-centralised P2H system production costs can **reach 2.6 €/kg**, improving the economics of P2H (electrolysis) significantly.

Conclusions and Recommendations

- Semi-centralised P2H could lead to significant environmental benefits and lower H2 production costs making low-carbon H2 an attractive option.

  → We encourage industrial regions to explore the P2H option as a collective option/investment for their decarbonisation needs.

- Fuel Cell technology for forklifts and captive fleets has recently been rolled out.

  → The expected FC technology cost reduction has the potential to establish H2 as one of the commonly chosen options next to batteries and other fuels.

- Electricity costs appear as the key factor in improving Low-Carbon H2 economics.

  → Electricity taxation policy has to be re-evaluated on the basis of accelerating the adoption of Low-Carbon H2 both in industry and mobility.